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Logistics micro-platforms as points of supply in case of a disaster

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Abstract

Within a city, the logistics are always related to the commercial activities and do not take into account the occurrence of an emergency. This study aims to change the mindset that the use of a distribution center is merely commercial, and proposing find a secondary use related to humanitarian logistics aspects. The novel of the study is the combination of humanitarian logistics with new urban logistics strategies, through mathematical modeling.

Keywords: Urban logistics; micro-platforms; humanitarian logistics.

1. Logistics and humanitarian logistics

This paper takes into account the possibility to use urban logistics micro-platforms as points to supply goods with a pre-positioned policy during the preparedness phase of a disaster. The proposed model includes a criterion considering the social cost to lose a life by starvation, as well as for other reasons very common in the humanitarian logistics operations. The novel of the study is the combination of humanitarian logistics with new urban logistics strategies. The model was solved through branch and bound by GAMS-CPLEX observing interesting results.

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1.1. Humanitarian logistics

Although humanitarian logistics and trade logistics have in common the orientation distribution of goods and resources, a remarked difference is shown from the approach of the target customer, the associated costs and environment in which they are developed, the characteristics of relief distribution networks, among others.

Humanitarian logistics has been aligned with the activities of various Non-Governmental Organizations (NGOs), traditionally related to development aid or humanitarian action [1], through the development of international projects. To clarify the difference between development and humanitarian action, their definitions are introduced below:

- The development activities are actions that are planned and developed in the medium to long term, looking to provide basic services permanently to a community, contributing to their self- sufficiency and to solve structural or chronic problems [2]
- The activities of humanitarian or emergency assistance (relief activities) are actions that take place in the short term, looking to provide goods and services necessary for survival of populations affected by a catastrophe, caused naturally or by human action [3]

The term "humanitarian logistics" has not reached a consensus on its definition, but it is involved in almost all activities related to humanitarian and development cooperation. From the logistics approach it has been defined as "the process of planning, implementing and controlling with high efficiency the flow of products, materials and information from the point of origin to point of consumption in order to alleviate the suffering of the vulnerable population" [4]. From the humanitarian approach, defined as "the processes and systems involved in mobilizing people, resources, skills and knowledge to help vulnerable people affected by any disaster" [5]

It is necessary to differentiate between the concepts sudden humanitarian crises (disaster) and those crises sustained over time. Sudden crises require immediate response schemes considering the time as the critical factor, while crises sustained over time allow the development of an action plan in a better and longer way.

Depending on the type of crisis, the necessary humanitarian operations are designed to provide attention to it. [13] state that one of the main objectives in these humanitarian operations, is to design the transportation of supplies like first aid, food, water, equipment and rescue personnel from supply points to the large number of dispersed nodes where the population are located in order evacuate affected people to the shelters quickly or to distribute the humanitarian aid in an equitative way.

Operations related to humanitarian logistics are highly complex and require high cooperation and flexibility in processes, because they need immediate action to an unpredictable situation, regarding the goods and services demand, so that questions like: what, how much, when, where and how do you may distribute the humanitarian aid; are very common. However the biggest problem is meeting the demand for specific goods in a limited period of time, when hysteria and uncertainty are present in the human behavior.

Logistics is the most important element in the disaster relief efforts and it is what makes the difference between a successful or failed operation [5]. However this is the most expensive part in disaster relief since there has been estimated that the related logistics costs reached about 80% of total costs in a disaster relief [5]. Although cost is not the main criteria in a humanitarian chain, any chain is related with scarce resources and budget constraints must be taken into account [12]. And as [23] mentions, the deprivation costs let to determine the social costs in a humanitarian chain.

The phases of a humanitarian and emergency action are: mitigation, preparedness, response and recovery [6]. There exist a growing need to have efficient and effective systems at different stages of a disaster, but the stages of planning and response are the ones that require more focus to give prompt protection, rescue and supply to vulnerable populations. Similarly, the mitigation and recovery stages have a significant participation in the ability to reduce the impact of natural disasters.

1.2. Urban Logistics

The humanitarian logistics are a special kind of logistics, where the delivery times need to be lowered to the minimum. Within a city, the logistics are always related to the commercial activities and do not take into account the occurrence of an emergency. The urban logistics are described below as a part of the city system, showing that are a business priority that could be related to the humanitarian logistics as well, considering social features and giving priority to other criteria than cost minimization.

Urban logistics are defined as "the process of optimizing the logistics and transportation activities by private companies, with the support of advanced information systems in urban areas, considering aspects related to traffic congestion, vial safety, and the energy savings within a framework of economic market". [7] presents different logistics challenges to meet the needs of the inhabitants within an urban area. The distribution of goods is crucial to the economic movement in the city and the welfare of all of its inhabitants in an equitative way. The latter fact directly affects congestion, pollution, energy consumption, road safety, urban space utilization, living and social needs.

The problems of urban freight distribution and any disaster affect a wide range of stakeholders: the service providers (voluntary carriers, emergency logistics operators, medical and security services, among others), the beneficiaries (citizens, vulnerable groups, etc.), international, national and local authorities [8].

To carry out the attention of inhabitants, the distribution centers (DC) are used to fulfill the function of integrating the products in the emergency facilities and to link donors and potential beneficiaries, guaranteeing humanitarian aid distribution.

Traditionally these distribution centers require adequate space to carry out several commercial activities, and they are located outside the urban areas because of related public policies. The logistics centers concentrate and re-distribute the freight, regulate vehicular traffic and articulate freight units from different geographical locations. They also improve the productivity of transportation operations, capture significant volumes of cargo, allow efficient organization of consolidated shipments with combined freights to different customers, and they are also a node of articulation of different transportation modes [8]. Given the advantages of logistics centers, they are increasingly being incorporated in the plans and programs of urban land use.

While any disruption of the freight unit (consolidation or deconsolidation) and shipping (transportation mode shift) involves costs. The operation logistics center allows companies to manage the constraints due to municipal regulations and focus on a centralized urban as possible to avoid physical distribution costs deliveries with multiple stops and guaranteeing to get savings.

When any disaster occurs, the nearest the distribution center is located, the people can access faster to prior humanitarian aid. Therefore, a logistics support platform within the urban area can accomplish both, the commercial activities and the humanitarian logistics.

2. Literature review

Several proposals have been performed, as well as designs of optimization models in humanitarian logistics for disaster attention and relief, including considering models with a single criterion [14, 15, 16, 18, 19] and multi-criteria decision making [12, 13, 17, 20, 21, 22].

The study by [18] presents a logistics problem for emergency distribution of multiple items from a set of collection centers to distribution centers in affected areas. In this study, a flow model is formulated in multi period networks and multiple items to determine pickup and delivery routes for both vehicles and the amount of freight to be handled by the routes minimizing the amount of unmet demand over time. Similarly, the study from [21] formulates the design of a network for multiple items to maximize coverage, identifying critical paths for the response to an earthquake, minimizing time and maximizing the covered population (a bi-objective integer programming model).

3. Definition of the study unit

This study aims to find a secondary use of a distribution center to become a humanitarian logistics center when an emergency or a disaster occurs; considering that the main goal of the distribution center is merely commercial, the addition of the humanitarian component could be interesting as it can provide a new humanitarian perspective to the commercial activity.

According to Edgar Blanco [9], in an urban planning and logistics development in a city, the appropriate unit of analysis and measurement area is one square kilometer (km^2). The analysis of a Km^2 in different cities around the world by the Logistics Megacities Lab at Massachusetts Institute of Technology (MIT) allows setting appropriate distribution strategies in emerging markets. To develop a model of platform location and use of the same for disaster relief must be met with some constraints, among which are the following: Space constraint, not continuous noise to residential areas, cover the demand for people located in the selected area, the land use plans, vehicle constraints, among others.

Considering the km^2 as the unit of measurement for urban logistics, the methodology proceeds to select an area in the city of Bogota, Colombia. This selection was made considering that the area must be a dense urban zone, with at least 14,000 families living, equivalent to more than 56,000 inhabitants, as well as 66,000 extra people as fluctuant inhabitants (non-permanent residents) that also need to be in the area due to shopping and job related activities. The selected km2 was "Ciudad Salitre Occidental" in Bogota. This area is shown in the figure 1, where it can be seen that only a few spots have enough space to build any emergency facility.

Fig.1. Location of the selected Km2 in Bogotá City, Colombia

Source: Adapted from [10]

The study collected data on this km2 focusing on trade in goods stores and cargo handling. Data was gathered using a Global Position System (GPS) to get the geographical location of the stores and using formats designed by the Megacities Logistics Lab at MIT, where the information collected was: shop definition, shop inventory, roads and regulations, traffic count, disruptive violations and delivery tracking. With this information, three models were developed for the location of potential commercial and emergency facilities (distribution centers – DC), consolidating the freight and humanitarian aid better in delivery routes and developing appropriate urban planning policies that support the daily and extraordinary operation of the roads [10, 11]

With the gathered information and using the GPS software to add the coordinates (latitude, longitude) to create the geotracks map, more than 600 points of distribution (POD[†]) were determined. This 600 POD were clustered into 29 points (by blocks and street face) to minimize the number of nodes, in order to perform an adequate optimization through the model designed. The 600 POD and the 29 clusters are shown in the figure 2

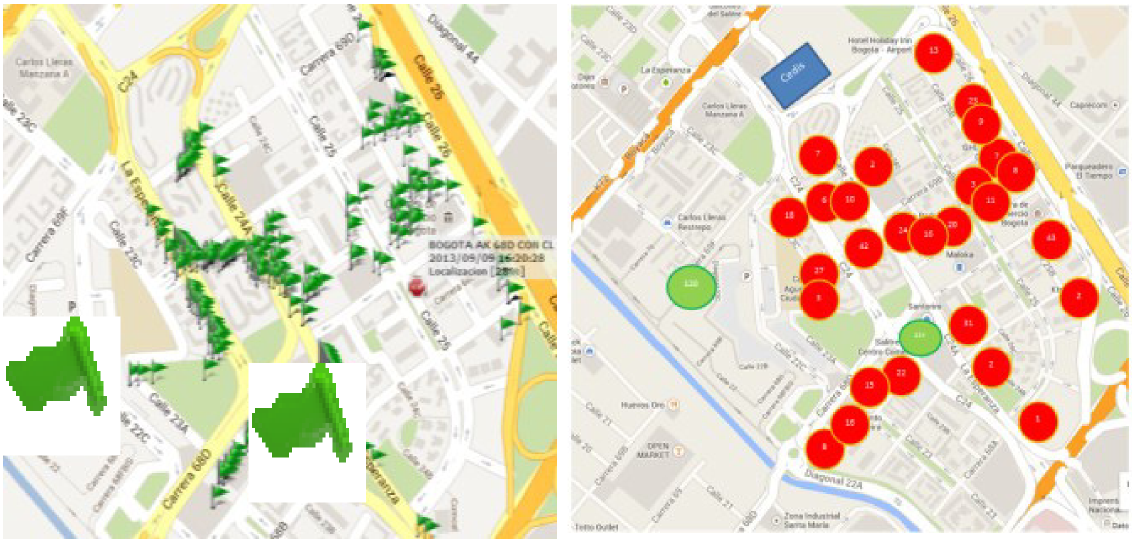

Fig. 2. Location of the POD and clusters in the Km2 in Bogotá, Colombia

Source: Adapted from [10]

On the figure in the left side, every flag is a POD, the 2 big flags are shopping malls: the one in the left side has 120 POD and the one in the center has 224 POD. On the figure at the right, the circles are the clusters per block and street face.

To determine the best location for the DC facility, a facility location optimization model was developed. It took into account all the constraints and variables required to meet the beneficiaries' needs, the period of time, costs on distribution, building cost, probability of a disaster occurrence, and social cost.

When talking about social costs, these are considered to have a critical social impact in the humanitarian logistics, but the analytical formulations are based on welfare economics [23]. On this study, this social cost is evaluated as the cost related to the loss of lives or goods, and its impact in the way of living.

4. Mathematical model

The DC's and the vulnerable population locations next to them were defined as the nodes (i), the most delivered products were defined as humanitarian aid needs (j), the possible locations for the DC were determined considering all the constraints as DC (k), and the period of time to meet the needs were defined as time (t).

As parameters were considered the demand of products in each node (d_{ij}^{t}), the capacity of the DC (c_{kj}), the travel cost to serve a vulnerable population location from the DC (co_{ki}), the attention time (Ta_{ki}), the maximum attention

[†] Points of distribution meet the demand of any potential beneficiary.

time on an emergency (Tam_i), the probability of a disaster occurrence (Pd_i^t) and the social cost related to loss of lives and goods (cs_{ki}).

The variables were set as: Facility location (y_k) as a binary variable if DC is chosen or not, Humanitarian aid flow (X_{kij}^t) from the DC to the node in a period of time, and the visit (V_{ki}^t) as a binary variable if the node is visited from the DC in a period of time.

The Objective Function was defined as:

$$\boldsymbol{Min\ Z = \sum_{kijt} co_{ki} X_{kij}^t + \sum_k bc_k Y_k + \sum_{kit} cs_{ki} V_{ki}^t} \tag{1}$$

Subject to the following constrains:

$$\sum_{k \in K} X_{kij}^t \geq d_{ij}^t \quad \forall\, i \in I, j \in J, t \in T \tag{2}$$

$$\sum_{k \in K} Y_k = 1 \tag{3}$$

$$\sum_{i \in I} X_{kij}^t \leq c_{kj} Y_k \quad \forall\, k \in K,\ j \in J, t \in T \tag{4}$$

$$\sum_{k \in K} V_{ki}^t Ta_{ki} \leq Tam_i \ \forall\, i \in I, t \in T \tag{5}$$

$$\sum_{k \in K} V_{ki}^t = Pd_i^t \ \forall\, i \in I, k \in K, t \in T \tag{6}$$

$$\sum_{i \in I, t \in T} V_{ki}^t \leq MY_k \ \forall\, i \in I, k \in K, t \in T \tag{7}$$

And the type of variables:

$Y_k \in \{0,1\},\ \forall\, k \in K$ → *1 if DC k is built, 0 otherwise*

$X_{kij}^t \in \mathbb{Z}^t,\ \forall\, i \in I, j \in J, k \in K, t \in T$ → *Continuous variables*

$V_{ki}^t \in \{0,1\}, i \in I, k \in K, t \in T$ → *1if the disaster happens and is attended, 0 otherwise*

The objective function (1) is to minimize the cost of building the distribution center *k*, minimize the travel cost to get to all nodes *i* where vulnerable populations are located, supply the demand for products *j* in the period of time *t* and minimize the social cost to get all the nodes *i* and visit them in a period of time *t*. The first constraint (2) shows that the humanitarian aid flow need to be equal or greater than the demand; the second constraint (3) mark out that one and only one distribution center needs to be built (this constraint can be changed to considered more than one DC in the modeled area); the third constraint (4) shows that the humanitarian aid flow needs to be equal or less than the capacity of the distribution center built; the fourth constraint (5) shows that the time required to supply a vulnerable populated zone is lower or equal to the maximum allowed time to attend an emergency; the fifth constraint (6) shows that if exists an emergency, the visit will be made, otherwise it will not be necessary; the sixth constraint (7) shows that the visit will be made always if the DC has been chosen to meet the emergency.

5. Conclusions and future work

The presented model is a classified as a "pure integer model" consisting of integer and binary variables that make it a hard problem to solve, for this "branch and bound" is used to facilitate the search for exact solutions.

The proposed formulation is a model that integrates market needs in terms of consumer products and social aspects of a community, trying to adapt common distribution centers as supply points during disasters in megacities. For this, an occurrence estimation of an emergency at each node at different periods of time is performed.

As this problem has a strong social component in the objective function, a social cost is included covering aspects related to delay time attention to every node, penalizing the deprivation costs, etc.

For future research, a classification of the different types of emergencies and an assignment priority will be made, considering that not all may be meet at the same time. Also it will be studied the required capacity of the micro-platform, to take care of the emergencies in any period of time, in order to measure when the system may collapse.

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